BISMUTH

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Bismuth was last produced domestically, as a byproduct of lead refining, at a Nebraska refinery that closed in 1997. The last stocks of bismuth held in the National Defense Stockpile were sold that same year. In 2004, all primary bismuth consumed in the United States was imported. Only a small amount of bismuth was obtained by recycling old scrap. The leading foreign producers of refined bismuth in 2004, in decreasing order of production, were China, Mexico, Belgium, Peru, and Japan. Belgium had no mine production, and its sole bismuth producer refined metal from smelter residues and flue dust, anode slimes, and concentrates, all of foreign origin.

Bismuth consumption in the United States during 2004 was estimated to be 2,420 metric tons (t), an increase of about 14% when compared with that of 2003. As a result of an ongoing U.S. Geological Survey (USGS) analysis and evaluation of the bismuth market begun in 2003, end-use patterns for 2003 and 2004 contain different assumptions than in previous years. The estimated domestic consumption of bismuth for 2004 was about 46% for metallurgical additives in alloying and galvanizing; 29% for bismuth alloys, fusible alloys, solder, and ammunition; 24% for chemical and pharmaceutical uses; and 1% for research and other uses (table 2).

In recent years, new uses for bismuth have been developed as a nontoxic substitute for lead. These include the use of bismuth in galvanizing (zinc) baths, brass plumbing fixtures, free machining steel, fire assaying, ceramic glazes and crystal ware, fishing weights, shot for waterfowl hunting, lubricating greases, pigments, and solders.

The average annual dealer price for bismuth increased to an estimated $3.22 per pound in 2004, an increase of 12% from the estimated average of $2.87 per pound in 2003 (table 1). An abundant supply of bismuth from China helped to moderate the price increases in light of strong growth in global demand.

The estimated value of bismuth consumed domestically in 2004 was about $17.2 million. The combination of an increase in consumption and an increase in average price resulted in the value of the bismuth consumed increasing by about 22% compared with that of 2003.

Legislation and Government Programs

The Safe Drinking Water Act Amendments of 1996 (Public Law 104-182) have banned lead from all fixtures, fluxes, pipes, and solders used for the installation or repair of facilities providing potable drinking water since 1998. The ban prompted a conversion to plumbing alloys that contain bismuth rather than lead. Increased use of plastic pipe, however, has kept the use of bismuth-alloyed brasses from growing more rapidly in plumbing applications.

The U.S. Environmental Protection Agency (EPA), in coordination with industry, was preparing a life-cycle assessment of the potential environmental impacts of lead-free solders in order to identify viable alternatives to traditional lead-tin solders. Several of the lead-free solder alternatives being considered contained bismuth (U.S. Environmental Protection Agency, 2002§[1]). In early 2005, the EPA released a draft report for public review and comment entitled "Solder in Electronics: A Life-Cycle Assessment." The life-cycle assessment evaluated impacts related to material consumption, energy use, air resources, water resources, landfills, human toxicity, ecological toxicity, and end-of-life recycling (U.S. Environmental Protection Agency, 2005§).

The death of indigenous waterfowl from ingestion of lead fishing weights prompted three States (Maine, New Hampshire, and New York) to pass various lead use restrictions for fishing tackle. According to a study by the Cummings School of Veterinary Medicine at Tufts University (Massachusetts), 20% to 50% of loon mortalities nationally were attributed to lead sinkers. Following the example set by Minnesota, some States were offering an exchange of lead tackle for lead-free alternatives. Bismuth is a popular choice since it has similar properties to lead. Lead sinkers, however, cost less than one-third the cost of equivalent bismuth or tungsten sinkers. Alternatives to lead, bismuth, and tungsten are steel or brass, which cost the same as lead but are less desirable because of their additional size (Burdi, 2004§; Star Tribune, 2004§).

Production

Domestic production of primary refined bismuth ceased in 1997. Some domestic firms continued to recover secondary bismuth from fusible alloy scrap in 2004, but secondary production data were not available. Secondary production was estimated to be less than 5% of domestic supply during the year.

Consumption

The USGS surveys domestic bismuth consumption annually. The amount used by nonrespondents is estimated based on reports from prior years or on information from other sources. Accordingly, estimated bismuth consumption was about 2,420 t in 2004, a

[1]References that include a section mark (§) are found in the Internet References Cited section.

14% increase from that of 2003 (table 1). As previously mentioned, the USGS is currently reevaluating the bismuth market; therefore, the use patterns for 2003 and 2004 contain different assumptions than those in previous years.

Consumption of bismuth in chemical uses (chemicals, cosmetics, and pharmaceuticals) in 2004 decreased by about 5% compared with use in 2003. In 2004, the two leading uses, bismuth metallurgical additives and alloys, increased compared with those of 2003 by 34% and 9%, respectively (table 2). The “Other” uses category, which represents a little less than 1% of consumption, decreased in 2004.

Although it has the crystal structure of a semimetal, bismuth is often considered a metal. This crystal structure, along with several of its other salient properties, makes it an ideal substitute for lead in extreme-pressure additives. These unique properties include expansion on solidification, the widest range between melting and boiling points among metals, and lowest thermal and heat conductivity. Bismuth is the most diamagnetic of all metals, the least toxic, and has lowest absorption for neutrons; bismuth is also characterized as “soft” like lead (Rohr, 2000).

Bismuth pharmaceuticals include the well-known bismuth subsalicylate (the active ingredient in over-the-counter stomach remedies) and other bismuth medicinal compounds used to treat burns, intestinal disorders, and stomach ulcers in humans and animals. Bismuth nitrate is the initial material used for the production of most bismuth compounds. Other applications of bismuth chemicals and compounds include uses in superconductors and pearlescent pigments for cosmetics and paints.

Bismuth metal is used primarily as a major constituent of various alloys and as a metallurgical additive (table 2). One class of bismuth alloys consists of fusible (low-melting-point, as low as 20° C) alloys—combinations of bismuth with other metals, such as antimony, cadmium, gallium, indium, lead, and tin. Applications for these alloys include fuel tank safety plugs, holders for lens grinding and other articles for machining or grinding, solders, and fire sprinkler triggering mechanisms.

In addition to the lead-free solder noted above, bismuth has long been a substitute for the lead added to steel to provide greater machinability. A major domestic steel company began to use a bismuth-containing substitute for the leaded alloy nearly 20 years ago. Although bismuth has been successful in replacing lead in various applications, it has been challenged as a lead substitute by tin and tungsten (Cusack, 1999). Bismuth is also added in small amounts to aluminum (along with lead) and copper alloys to improve machinability. Further, it is added to malleable iron to prevent the formation of graphite flakes. These uses constitute the traditional metallurgical additives category.

Prices

The average dealer price for bismuth in 2004 increased to an estimated \$3.22 per pound in 2004, an increase of 12% from the estimated average of \$2.87 per pound in 2003 (table 1). The average annual price had been fairly steady from 1999 through 2001, with the typical bismuth price cycle consisting of long slow declines followed by fairly steep increases. In 2003, the weekly price range fell to \$2.60 to \$2.85 per pound, the lowest since 1993. The weekly price range started 2004 at \$2.70 to \$3.00 per pound. It remained relatively flat, rising to \$2.75 to \$3.05 per pound on April 8, before rising to \$3.50 to \$3.70 per pound at the beginning of June, the highest value for the year. Prices remained at this level until mid-August, when the weekly price range began a slow decline, finishing the year at \$3.25 to \$3.55 per pound.

Trade

U.S. bismuth exports by weight were almost unchanged from those of 2003 (increasing by less than 0.4%), while decreasing in value by about 20%. While bismuth prices rose for the year, the decrease of 20% in the value of exports was owing to shifts in the types of value-added bismuth products exported. Notable increases were seen in exports to Canada, the Dominican Republic, and the United Kingdom. Belgium, Japan, and Mexico experienced large drops in imports from the United States (table 3).

Total U.S. bismuth imports decreased by 14.3% by weight and increased by 0.8% by value in 2004 compared with the prior year’s figures (table 4). Bismuth imports were more than 18 times greater than exports. The leading import partner of the United States was Belgium, which supplied a little more then 40% of imports. Notable increases were seen in imports from Germany and the United Kingdom. Notable decreases were seen in imports from China, Hong Kong, and Mexico.

World Review

Throughout most of the world, bismuth is produced as a byproduct of smelting lead ores. In China, it is also a byproduct of tungsten, tin, and fluorspar ore processing. The Tasna Mine in Bolivia, the only mine that produced bismuth from bismuth ore, has been on standby since the mid-1990s awaiting a significant rise in the metal price. There are several other deposit types that may be developed soon that would have bismuth as a coproduct.

World refinery production of bismuth decreased by 6% in 2004 (table 5). China was the leading supplier of bismuth with almost 56% of the world’s total, followed by Mexico with about 14% and Belgium with about 10%.

In June, Hitachi Ltd. announced that it had eliminated lead in solder used in its electrical and electronics products made in Japan. To be in compliance with European Union (EU) lead-free regulations, the company began using indium for low-temperature soldering (Metal-Pages, 2004b§).

In a related announcement (also to meet EU lead-free regulations) Harima Chemicals, Inc., headquartered in western Japan, began the production of lead-free solder at its U.S. manufacturing and marketing subsidiary in Georgia. Harima’s solder combines bismuth, indium, silver, and tin. The solder has proven to be a good substitute, but costs approximately 30% more than lead solder (Metal-Pages, 2004c§).

Tiberon Minerals Ltd. (Canada), on behalf of Nui Phoa Mining Joint Venture Ltd. (Vietnam), signed a memorandum of understanding (MOU) with the world's leading bismuth producer Sidech SA (Belgium). Under the terms of the MOU, Sidech would purchase all of Nui Phoa Mine's bismuth output, anticipated to be 1,000 metric tons per year for the first 5 years, and would provide technical assistance with bismuth production. The agreement was expected to be finalized early in 2005, and the mine was projected to open in the third quarter of 2007 (Mining Journal, 2004; Platts Metals Week, 2004).

Fortune Minerals Limited (London, Ontario, Canada) started raising funds on the equity markets to continue development of two mining projects, one of which is the NICO gold-cobalt-bismuth deposit located 160 kilometers northwest of Yellowknife, Northwest Territories, Canada. The resources at this deposit were estimated to be 13.4 million metric tons (Mt) grading 1.62 grams per metric ton (g/t) gold, 0.14% cobalt, and 0.16% bismuth. Calculated at cobalt prices of $15 per pound, the resource expands to 24.6 Mt grading 1.02 g/t gold, 0.12% cobalt, and 0.14% bismuth. The feasibility study for the project was scheduled to be completed in the first half of 2005 (Metal-Pages, 2004d§).

Current Research and Technology

In the EU, Japan, and the Republic of Korea, researchers continued to develop system solutions for advanced and sustainable lead-free soldering. The Next Generation Environment-Friendly Soldering Technology (EFSOT) effort is an intelligent manufacturing systems project. Almost 60% of the effort would be expended on the upgrading of soldering technology as well as new material and process technology; 20% of the effort would be to investigate the biological impacts of soldering materials; about 10% of the effort would be to examine the environmental impact, including evaluations of resource depletion and metal toxicity issues; and the final stage, about 10% of the effort, would be to investigate recycling and component recovery (EFSOT, 2004§). A preliminary study by EFSOT scientists on oral and intratracheal toxicity and the carcinogenicity of lead-free metals showed bismuth to have acute or single dose toxicity equal to that of antimony, indium, lead, and silver. The oral "no observed affect level" or chronic toxicity level, however, was very low. Intratracheal administration of bismuth to laboratory rats showed no effects on measured indicators. Bismuth was found not to be mutagenic in initial tests, and therefore probably not carcinogenic, and on chromosome aberration tests, the metal showed mutagenicity in only 6% of the tests with a dose of 5 grams per milliliter of bismuth (Sato and others, 2004§). A portion of a study analyzing the biological impact, environmental effects, and recycling criteria was planned for completion in September 2005 (EFSOT, 2004§).

A recent survey showed that the Japanese electronics industry was still behind the schedule set by the Japan Electronics and Information Technology Industries Association (JEITA), which had called for a 50% conversion to lead-free solders by 2002. The lack of a standardized method for evaluating the reliability of lead-free solders has caused Japanese electronics manufacturers to resist a change to lead-free solders. The JEITA, therefore, instituted a project to establish standards for lead-free solders to be completed by the end of 2003. The objective, however, remained a goal for the Japanese industry in order to comply with the EU's schedule for purchasing only lead-free electronics by 2006 (Metal-Pages, 2003a§).

Recent research interest into liquid lead-bismuth coolant nuclear reactor technologies has been spawned by some major inherent safety advantages compared to the traditional technologies using molten sodium. The lead-bismuth mix has a melting temperature of 123.5° C, a boiling point of 1,670° C, and 0.0% expansion upon melting; in the core of a fast reactor, there would be small energy lost per particle collision with heavy metals. These features offer important advantages in terms of plant simplification, inherent/passive safety, and achievable proliferation resistance. The Russians have used this technology in some nuclear powered submarines, and they continued to do research. A great deal of research would still be required for a heavy-metal coolant proliferation-resistant reactor prototype to be built in the West (Spencer, 2000).

Bismuth-209, which for decades was believed to be the heaviest naturally occurring atom that never decays, has recently been found to radioactively decay. Its half-life was estimated to be 19 quintillion (billion billion) years (De Marcillac and others, 2003; Weiss, 2003).

AlphaMed Inc. (Massachusetts) announced it had received a $500,000 grant to further develop radiotherapy for metastatic melanoma. In conjunction with the University of Missouri (Columbia, MO), AlphaMed was to supply the lead-212 and bismuth-212 generators needed for research into developing a cure for this type of melanoma (Mass High Tech, 2003§).

Maxell Corporation of America announced a breakthrough in high-speed rewritable optical recording devices. Its new DVD–RAM disc uses a bismuth coupling material (BCM) recording layer that improves the quality of high-speed recording and is four times faster than current technology. The new disc also increases the storage capacity to 4.7 gigabytes, which is about 6 hours of video. The BCM recording layer also increases the shelf life for the DVD–RAM disc (PC World, 2004§).

Work continued on finding an environmentally friendly alternative to lead in small arms ammunition. Alliant Techsystem Inc.'s ATK ammunition division, producer of 3.4 billion bullets per year, was working to develop a bismuth-containing metal polymer bullet. Lead bullets in current use are far less expensive if one does not consider the environmental cleanup, which can cost three times more than the bullet itself (Metal-Pages, 2003b§).

Nanophase Technologies Corporation (Romeoville, IL) developed a commercial-scale process for producing bismuth oxide nanomaterials. This nanoscale material can be incorporated into specialty materials for bone implants and other medical applications. The advantage of this new material is that it is readily detectable by x rays without the toxic and carcinogenic attributes of other heavy metals. When incorporated into plastics, this material also can be used to detect plastic firearms at security stations or the locations of plastic toys if swallowed by a child (Nanophase Technologies Corporation, 2003).

American Superconductor Corporation (Westbough, MA) was marketing and researching first-generation high-temperature superconductor (HTS) composite wire. Materials are considered HTS if they have a critical transition (to superconductivity) temperature above 77 K, the boiling temperature of liquid nitrogen. This wire is a composite structure consisting of filaments of HTS material embedded in a silver alloy matrix. The HTS material $Bi_{(2-0.x)}Pb_{(0.x)}Sr_2Ca_2Cu_3O_{10}$, is called BSCCO-2223 for short. American Superconductor has built a 5-megawatt (MW) prototype motor for the U.S. Department of the Navy using first-generation HTS wire (delivered July 2003) and was in the process of building a larger, 36.5-MW motor for the Navy. American Superconductor was also researching second-generation HTS wire that would be a superior superconductor and have a significantly reduced cost. Second-generation HTS wire uses $YBa_2Cu_3O_7$, called YBCO, and does not use bismuth (American Superconductor Corporation, 2005§).

Outlook

Indications were that worldwide demand for bismuth was increasing at about 5% per year (Metal-Pages, 2004a§). Demand for bismuth in the steel sector, although relatively minor compared with other use sectors, appeared to be rising. Consumption in the chemical sector was increasing as Japan turned to bismuth as a replacement for lead in pigments (Mining Journal, 2003).

Representative organizations from Europe, Japan, and North America agreed to a framework to eliminate lead from solder in manufacturing. This agreement will tend to increase the demand for bismuth during the next several years. Many Japanese manufacturers are using lead-free solder in some or all of their soldering applications, and studies on how best to develop lead-free solders were being performed independently by the EU, Japan, the Republic of Korea, and the United States (EFSOT, 2004§). Although overall lead consumption was expected to be reduced by only 0.8%, overall bismuth consumption would increase by about 25% with a move to lead-free solders (Deubzer and others, 2004§). Although metal alloy solders using bismuth and other nontoxic metals were being pursued as a short-term solution to lead-free electronics, research into “smart glues” may provide a metal-less solution in the longer term (Penman, 2003).

Work continued on finding an environmentally friendly alternative to lead that is less expensive than bismuth for use in small arms ammunition. Mitsubishi Materials Corporation developed a new composite material with the same density and hardness as lead. This new tungsten-based material was expected to overcome some of the problems related to bismuth in lead-free hunting ammunition (Metal-Pages, 2003b§).

A significant near-term increase in supplies of lead byproduct bismuth is unlikely because total world production of lead was expected to remain relatively stable, and an increasing fraction of lead demand was expected to be satisfied by recycling. Nevertheless, a global shortage of bismuth was not anticipated. In China, where bismuth is a byproduct of lead, tungsten, tin, and fluorspar processing, new technologies applied to this resource have increased world bismuth reserves (Werner, Sinclair, and Amey, 1998, p. 54). Therefore, despite any large increases in world demand, Chinese supplies can be expected to help keep the bismuth market stable (Mining Journal, 2001).

It appears that low prices in recent years were owing to the nearly constant availability of Chinese bismuth during the past decade, which in turn constrains bismuth supply to the market. Usually, more bismuth appears quickly in the market whenever prices increase. Thus, it appears that the limiting factor for bismuth supply is low prices, not the availability of the metal (Camak, 1999). The 2004 price rise, continuing even stronger into 2005, coupled with record world refined metal production (and presumed consumption) would lead one to believe that new uses are increasing both market demand and supply.

References Cited

Camak, Rachel, 1999, China not to blame for poor markets: Metal Bulletin, no. 8422, November 1, p. 7.
Cusack, Paul, 1999, New uses to boost tin consumption: Metal Bulletin Monthly, no. 344, August, p. 35.
De Marcillac, Pierre, Coron, Noël, Dambier, Gérard, Leblanc, Jacques, and Moalic, J.P., 2003, Experimental detection of particles from the radioactive decay of natural bismuth: Nature, v. 422, no. 6934, April 24, p. 876-878.
Mining Journal, 2001, Minor metals in January: Mining Journal, v. 336, no. 8619, February 2, p. 91.
Mining Journal, 2003, Minor metals in December: Mining Journal, v. 340, no. 8717, January 3, p. 13.
Mining Journal, 2004, Bismuth off-take deal: Mining Journal, December 3, p. 7.
Nanophase Technologies Corporation, 2003, Nanophase Technologies announces commercial availability of nanocrystalline bismuth oxide: Romeoville, IL, Nanophase Technologies Corporation press release, August 28, 1 p.
Penman, Danny, 2003, Smart glue could spell the end for solder: New Scientist, v. 179, no. 2407, August 9, p. 23.
Platts Metals Week, 2004, Tiberon, Sidech in bismuth offtake deal: Platts Metals Week, v. 75, no. 48, November 20, p. 9.
Rohr, Otto, 2000, Get the lead out: Lubricants World, p. 28-30.
Spencer, B.W., 2000, The rush to heavy liquid metal reactor coolants—Gimmick or reasoned; Baltimore, Maryland, International Conference on Nuclear Engineering, 8th, Baltimore, MD, April 2-6, 2000, Proceedings, 13 p.
U.S. Environmental Protection Agency, 2000, EPA announces tough new standards for lead: Washington, DC, U.S. Environmental Protection Agency press release, December 26, 2 p.
Weiss, Peter, 2003, Not even bismuth-209 lasts forever: Science News, v. 163, no. 18, May 3, p. 286.
Werner, A.B.T., Sinclair, W.D., and Amey, E.B., 1998, International Strategic Mineral Issues summary report—Tungsten: U.S. Geological Survey Circular 930-O, 71 p.

Internet References Cited

American Superconductor Corporation, 2005, Revolutionizing the way the world uses electricity, accessed June 30, 2005, via http://www.amsuper.com.
Burdi, Jerome, 2004 (April 24), Lead sinker sales to cease across state, The Saratogian, accessed April 26, 2004, via URL http://www.saratogian.com.
Deubzer, Otmar, Reichl, Hafahide, Cacho, Inigo, Miguel, Rafael, and Irasarri, Lewis, 2004 (January 15), EFSOT (next generation environment-friendly soldering technology)—Recycling and resource consumption, accessed February 3, 2004, via URL http://www.efsot-europe.info.
EFSOT, 2004 (February 17), EFSOT—Next generation environment-friendly soldering technology, accessed April 12, 2004, via URL http://www.efsot-europe.info.
Mass High Tech, 2003 (August 13), AlphaMed wins $500k grant, accessed November 7, 2003, via URL http://www.masshightech.com.
Metal-Pages, 2003a (July 29), Japan slow to take up lead-free solders, accessed June 26, 2003, via URL http://www.metal-pages.com.
Metal-Pages, 2003b (October 16), Mitsubishi develops tungsten based ammunition, accessed October 17, 2003, via URL http://www.metal-pages.com.

Metal-Pages, 2004a (January 23), Business as usual for bismuth, accessed January 26, 2004, via URL http://www.metal-pages.com.
Metal-Pages, 2004b (June 2), Solders—Pb out, In in, accessed March 16, 2005, via URL http://www.metal-pages.com.
Metal-Pages, 2004c (November 11), Solders—Harami solders on without lead, accessed March 16, 2005, via URL http://www.metal-pages.com.
Metal-Pages, 2004d (December 24), NICO Co-Bi project to get boost from $20m fortune placement, accessed March 16, 2005, via URL http://www.metal-pages.com.
PC World, 2004 (June 8), DVD-RAM hits surprising speeds, accessed June 9, 2004, via URL http://www.pcworld/resource/printable/article/0,aid,11438,00.asp.
Sato, H.H., Okamoto, Hasahide, and Deubzer, Otmar, 2004 (January 15), EFSOT (next generation environment-friendly soldering technology)—Biological impact, accessed February 3, 2004, via URL http://www.efsot-europe.info.
Star Tribune, 2004 (April 28), Outdoors note—Officials to offer lead tackle exchanges, accessed April 28, 2004, via URL http://www.startribune.com.
U.S. Environmental Protection Agency, 2002 (June), Design for the environment, lead-free solder partnership, assessing life cycle impacts in the electronics industry, accessed July 6, 2005, via http://www.epa.gov/opptintr/dfe/pubs/solder/solderfact.pdf.
U.S. Environmental Protection Agency, 2005 (July), Solder in electronics—A life-cycle assessment, via http://www.epa.gov/opptintr/dfe/pubs/solder/lca/index.htm.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Bismuth. Ch. In Mineral Commodity Summaries, annual.
Bismuth. Ch. In United States Mineral Resources, Professional Paper 820, 1973.
Bismuth. Mineral Industry Surveys, quarterly.

Other

Bismuth. Ch. In Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

TABLE 1
SALIENT BISMUTH STATISTICS[1]

		2000	2001	2002	2003	2004
United States:						
Consumption	metric tons	2,130	2,200	2,320	2,120	2,420
Exports[2]	do.	491	541	131	108	109
Imports for consumption	do.	2,410	2,220	1,930	2,320	1,980
Price, average, domestic dealer	dollars per pound	3.70	3.74	3.14	2.87	3.22
Stocks, December 31, consumer	metric tons	118	95	111	279 [r]	117
World:						
Mine production, metal content[3]	do.	3,790	4,420	3,690	3,810	NA [e]
Refinery production[4]	do.	4,230	5,050	4,400	4,630	NA [e]

[e]Estimated. NA Not available. [r]Revised.

[1]Data are rounded to no more than three significant digits.

[2]Comprises bismuth metal and the bismuth content of alloys and waste and scrap.

[3]Excludes the United States.

[4]Excludes Canada.

TABLE 2
BISMUTH METAL CONSUMED IN THE UNITED STATES, BY USE[1]

(Metric tons)

Use	2003[2]	2004
Chemicals[3]	616	584
Bismuth alloys	646	703
Metallurgical additives	833 [r]	1,110
Other	25	22
Total	2,120	2,420

[r]Revised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]The U.S. Geological Survey is currently reevaluating the bismuth market; therefore, the end uses for 2003 contain different assumptions compared with previous years.
[3]Includes industrial and laboratory chemicals, cosmetics, and pharmaceuticals.

TABLE 3
U.S. EXPORTS OF BISMUTH METAL, ALLOYS, AND WASTE AND SCRAP, BY COUNTRY[1]

	2003		2004	
Country	Quantity (kilograms, metal content)	Value (thousands)	Quantity (kilograms, metal content)	Value (thousands)
Belgium	10,500	$28	2,720	$67
Brazil	1,800	34	1,140	156
Canada	23,500	363	46,000	812
China	992	9	99	3
Costa Rica	492	4	--	--
Dominica	--	--	53	9
Dominican Republic	2,320	294	11,100	664
Egypt	448	8	--	--
Germany	4	4	1	3
Guatemala	143	4	229	4
Hong Kong	155	28	360	70
Hungary	136	3	--	--
Israel	7	4	--	--
Italy	--	--	113	18
Japan	30,200	2,000	5,320	102
Korea, Republic of	496	8	75	5
Mexico	33,300	261	28,500	488
Russia	1,510	20	2,090	33
Singapore	--	--	59	20
Thailand	250	42	--	--
United Kingdom	1,840	21	10,700	48
Total	108,000	3,130	109,000	2,500

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 4

U.S. IMPORTS FOR CONSUMPTION OF METALLIC BISMUTH, BY COUNTRY[1]

Country	2003 Quantity (kilograms)	2003 Value (thousands)	2004 Quantity (kilograms)	2004 Value (thousands)
Bahamas, The	1,330	$18	1,910	$12
Belgium	778,000	5,170	793,000	5,740
Canada	22,500	156	8,760	664
China	573,000	3,610	169,000	1,280
Germany	67,100	156	162,000	809
Hong Kong	105,000	647	77,100	722
Italy	500	24	--	--
Mexico	532,000	3,020	495,000	3,310
Netherlands	57,900	461	232	25
Peru	135	2	39,800	298
Russia	--	--	52	12
Spain	756	9	500	6
United Kingdom	178,000	1,130	237,000	1,640
Total	2,320,000	14,400	1,980,000	14,500

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 5

BISMUTH: WORLD MINE AND REFINERY PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country	Mine					Refinery				
	2000	2001	2002	2003[e]	2004[e]	2000	2001	2002	2003[e]	2004[e]
Belgium[e]	--	--	--	--	--	700	700	1,000	1,000	800
Bolivia	6 [r]	8 [r]	20 [r]	72 [r]	60	14	66	88 [r]	88 [r]	50
Bulgaria[e]	40	40	40	40	40	40	40	40	40	40
Canada[3]	243	258	189	145 [r]	145	250 [e]	250 [e]	250 [e]	250	250
China[e]	1,120	1,250	1,700 [r]	2,100 [r]	2,500	770	1,230	2,600 [r]	4,800 [r]	4,500
Italy[e]	--	--	--	--	--	5	5	5	5	5
Japan[e, 4]	26	28	24	26 [r]	23	520 [5]	551	474	513 [r]	460
Kazakhstan[e]	130	252	161	150	150	55	130	130	130	130
Mexico	1,112 [6]	1,390 [6]	1,126	1,064 [r, 5]	1,100	1,083	1,390	1,126	1,064 [r, 5]	1,100
Peru	1,000 [e]	1,000 [e]	1,000 [e]	1,000	1,000	744	640	568	600 [r]	600
Romania[e]	40	40	40	40	40	35	35	35	35	35
Russia[e]	50	50	50	50	50	10	10	10	10	10
Serbia and Montenegro[e]	2	2	2	1	--	--	--	--	--	--
Tajikistan	5	5	--	--	--	--	--	--	--	--
United States	W	W	W	W	W	--	--	--	--	--
Total	3,800 [r]	4,300 [r]	4,400 [r]	4,700 [r]	5,100	4,200	5,000	6,300 [r]	8,500 [r]	8,000

[e]Estimated. [r]Revised. W Witheld to avoid disclosing company proprietary data; not included in "Total." -- Zero.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through April 4, 2005. Bismuth is produced primarily as a byproduct of other metals, mainly lead and tungsten.

[3]Figures listed under mine output are the metal content of concentrates produced, according to Natural Resources Canada.

[4]Mine output figures have been estimated to be 5% of reported metal output figures.

[5]Reported figure.

[6]Refined metal plus bismuth content of impure smelter products.